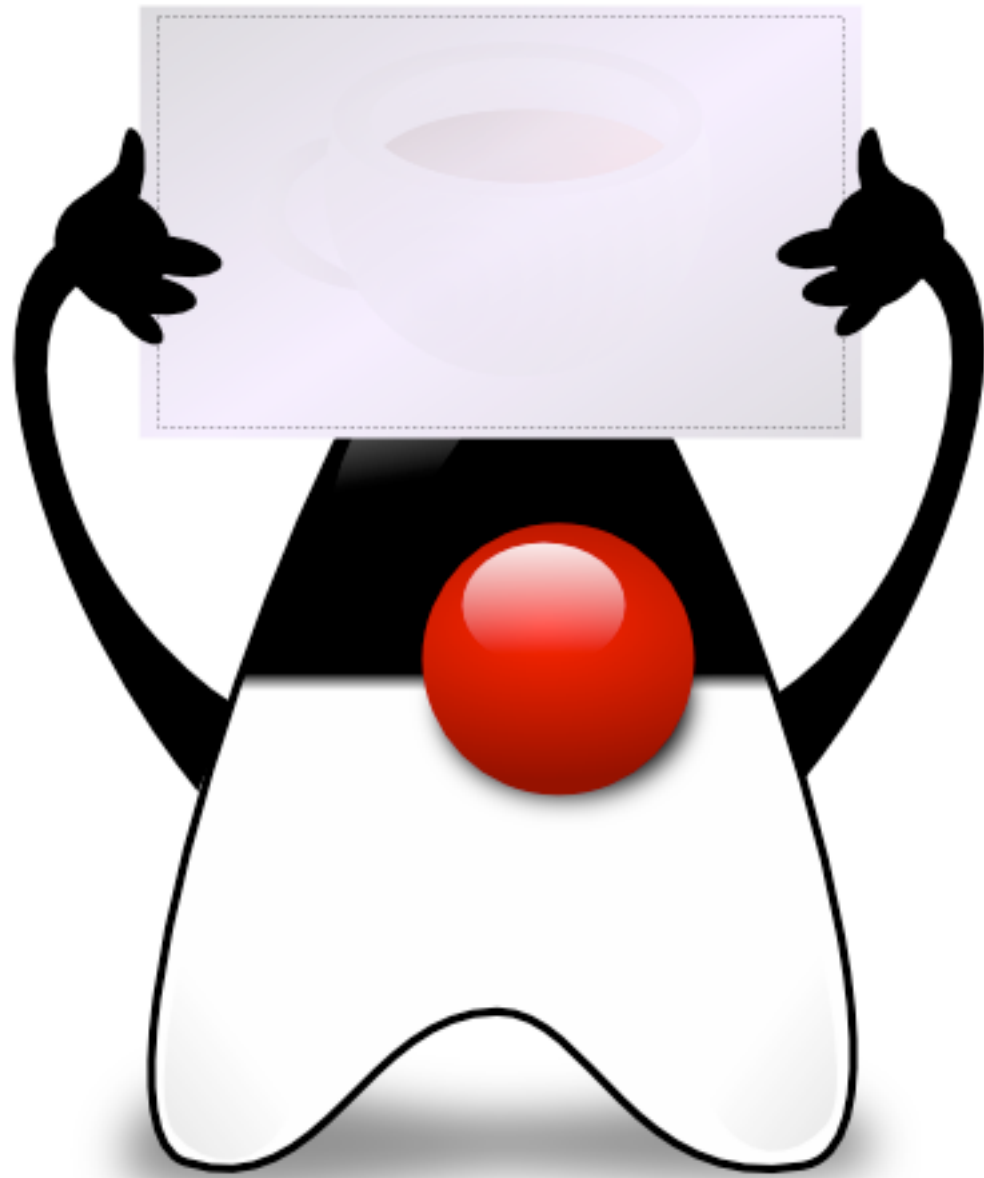


05 - Persistence tier (3)

ORM in Java EE: Java Persistence API (JPA)

AMT 2018

Olivier Liechti



JDBC without copy-paste



JDBC is pretty straightforward, but... isn't it **verbose and repetitive**?

```
@Stateless
public class SensorJdbcDAO implements SensorDAOLocal {

    @Resource(lookup = "jdbc/AMTDatabase")
    private DataSource dataSource;

    public List<Sensor> findAll() {
        List<Sensor> result = new LinkedList<>();
        try {
            Connection con = dataSource.getConnection();

            PreparedStatement ps = con.prepareStatement("SELECT * FROM Sensors");
            ResultSet rs = ps.executeQuery();

            while (rs.next()) {
                Sensor sensor = new Sensor();
                sensor.setId(rs.getLong("ID"));
                sensor.setDescription(rs.getString("DESCRIPTION"));
                sensor.setType(rs.getString("TYPE"));
                result.add(sensor);
            }

            ps.close();
            con.close();

        } catch (SQLException ex) {
            Logger.getLogger(SensorJdbcDAO.class.getName()).log(Level.SEVERE, null, ex);
        }
        return result;
    }
}
```

When I implement the UserDAO, the RoleDAO, the LocationDAO, will I need to **repeat** all the code around those statements (**boilerplate**)?

Will I need to manually replace the **table and column names** in each DAO?

And when I **maintain** my application, what happens when a new property is added? Do I have to **update my DAO**?

```
@Stateless
public class SensorJdbcDAO implements SensorDAOLocal {

    @Resource(lookup = "jdbc/AMTDatabase")
    private DataSource dataSource;

    public List<Sensor> findAll() {
        List<Sensor> result = new LinkedList<>();
        try {
            Connection con = dataSource.getConnection();

            PreparedStatement ps = con.prepareStatement("SELECT * FROM Sensors");
            ResultSet rs = ps.executeQuery();

            while (rs.next()) {
                Sensor sensor = new Sensor();
                sensor.setId(rs.getLong("ID"));
                sensor.setDescription(rs.getString("DESCRIPTION"));
                sensor.setType(rs.getString("TYPE"));
                result.add(sensor);
            }

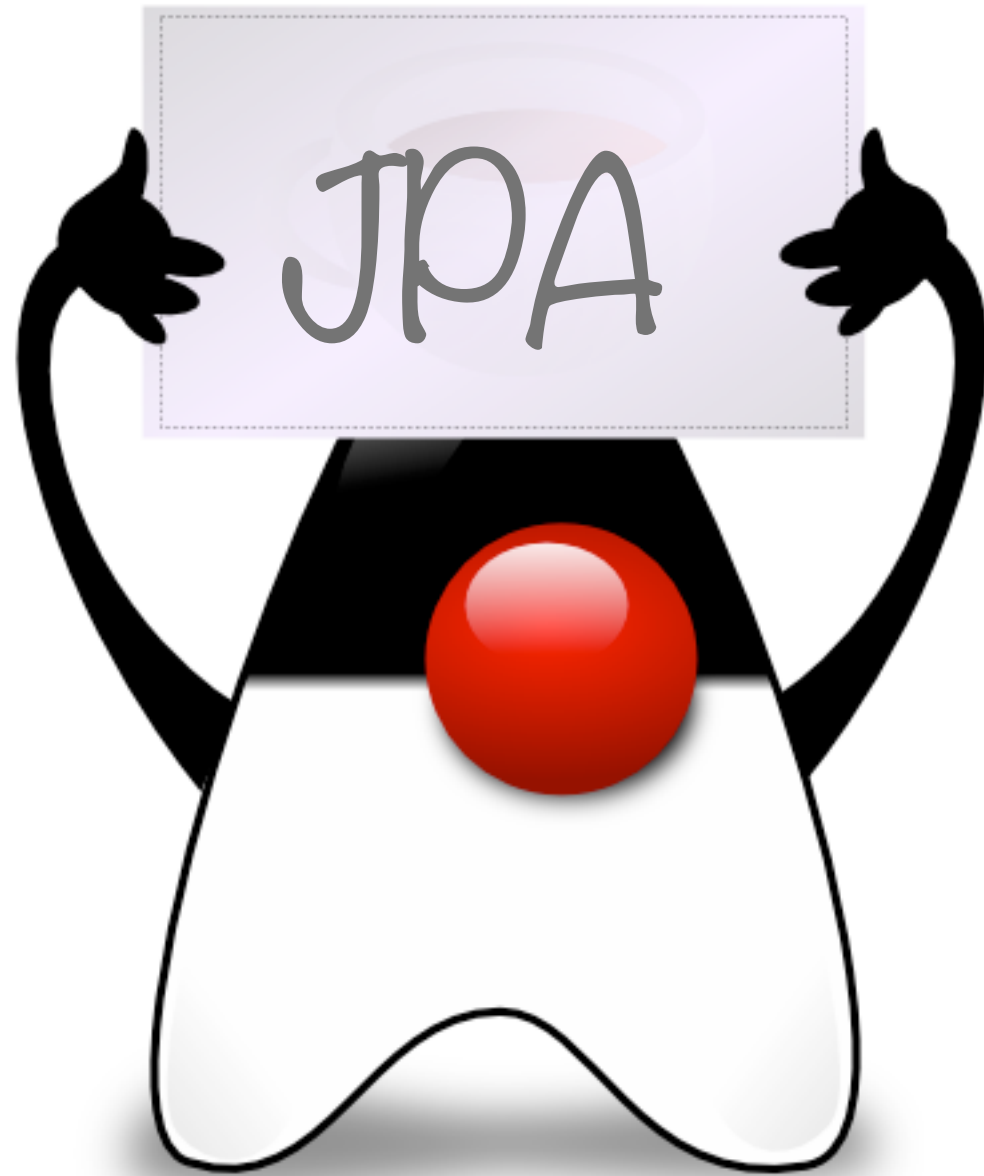
            ps.close();
            con.close();
        } catch (SQLException ex) {
            Logger.getLogger(SensorJdbcDAO.class.getName()).log(Level.SEVERE, null, ex);
        }
        return result;
    }
}
```

Reflection sounds cool. Can't we use it to deal with JDBC in **more generic** ways?

JDBC gives me **metadata** about the DB schema.

Reflection gives me ways to dynamically find and **invoke methods** on Java objects.

Can we combine these features to make this code better?



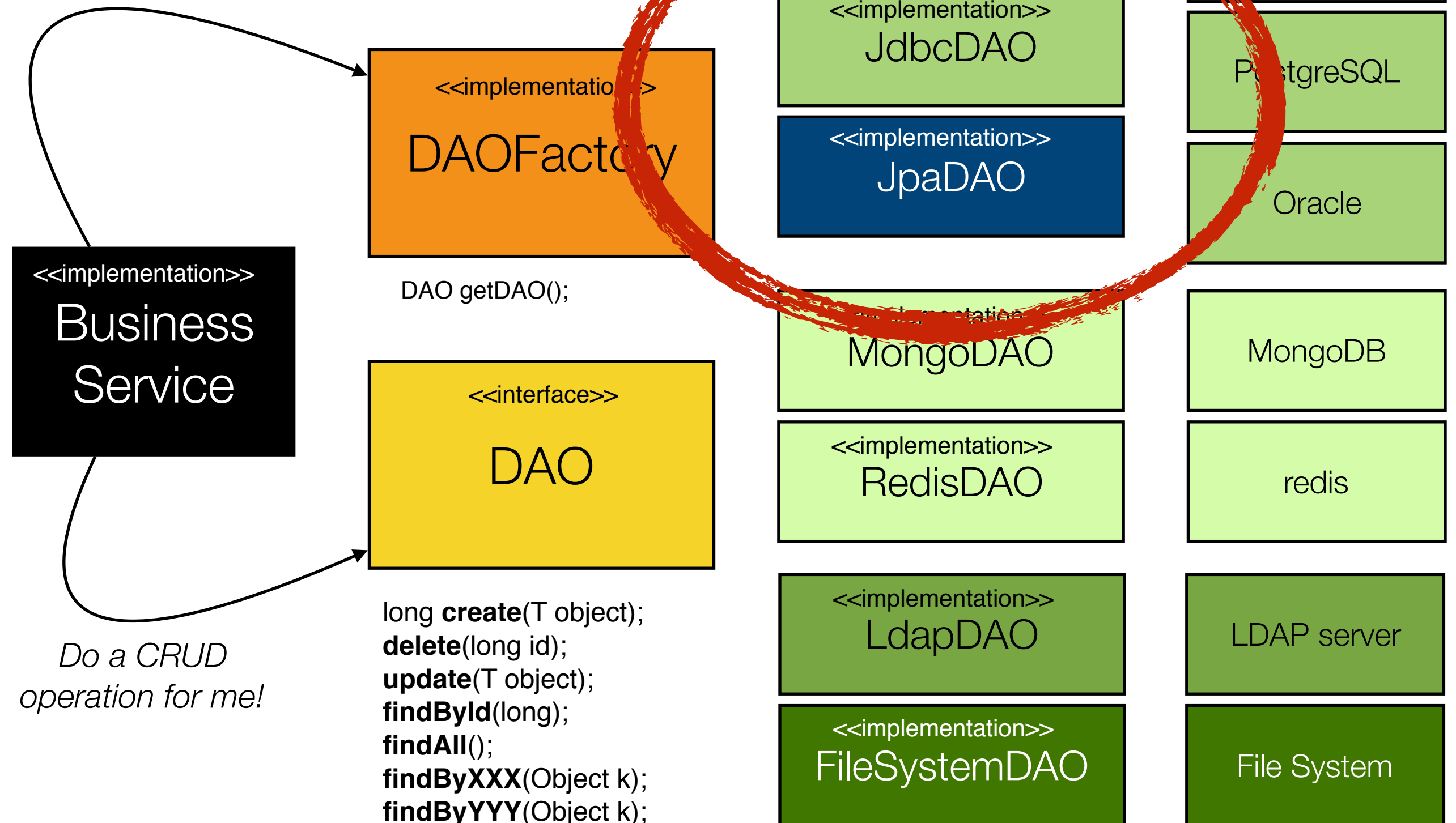
Java Persistence API (JPA)



Foreword

- Today, we will **introduce** the **JPA API** and **related concepts**.
- In **future lectures**, we will come back and look at the details of transactions, associations, JPQL queries, etc.
- The objectives after today's lecture are:
 - to be able to **implement a simple JPA entity** (without associations)
 - to be able to **inject and use an EntityManager** in a **DAO**, in order to **create, update, delete** and **find** information in the database.
 - to write **simple JQPL queries** in the entity class, in order to write the finder methods.

Give me a DAO implementation!





What is **JPA**?

- JPA is a **standard API** for accessing **RDMS** from Java applications.
- JPA is a **higher-level API** than JDBC and is based on Object-Relational Mapping (ORM).
- When you use JPA, you do not have to write all SQL queries sent to the database. They are **automatically generated** by the JPA implementation.
- Java Persistence API was originally specified in JSR 220 (JPA 2.0 in JSR 317, JPA 2.1 in JSR 338).
- **JPA is part of Java EE**. This means that every compliant application server **has to** provide a JPA implementation.
- Historically, the design of JPA was greatly influenced by the **Hibernate framework**. Hibernate is one of the most popular JPA implementations (and provides features that are outside the scope of the specifications).

With JPA, you define an object-oriented domain model. You work with business objects, specify relationships between them.

You live in the wonderful world of objects.

And you let JPA handle the interactions with the database. The schema can be generated automatically, the SQL queries as well.

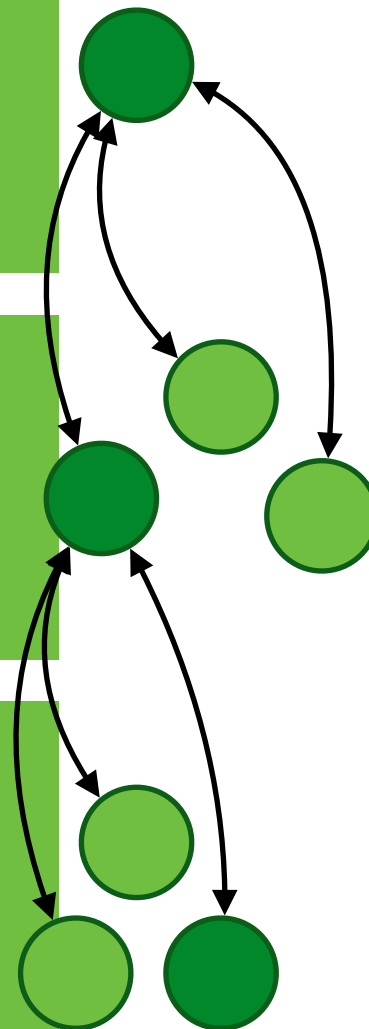


How do we move between the world of **objects** and the world of **relations**?

```
public interface ICustomer {  
    public String getFirstName();  
    public String getLastName();  
    public List<Order> getOrders();  
}
```

```
public interface IOrder {  
    public ICustomer getCustomer();  
    public List<OrderLine> getLines();  
    public double getTotal();  
}
```

```
public interface IOrderLine {  
    public Order getOrder();  
    public double getUnitPrice();  
    public double getQuantity();  
    public double getItemRef();  
}
```



CUSTOMER

ID	FIRSTNAME	LASTNAME	EMAIL
101	Olivier	Liechti	x.x@x.com
102	John	Doe	j.d@x.com
103	Paul	Smith	p.s@x.com

ORDER

ID	CUST_ID	DATE	TOTAL	STATUS
10230	101	02.03.2014	122.30	SHIPPED
20983	101	13.06.2014	256.00	SHIPPED
22099	101	18.07.2014	78.50	SHIPPED

ORDERLINE

ID	ORDER_ID	ITEM	QTY	U.PRICE
89123	20983	989	1	56
89124	20983	123	1	100
89125	20983	223	4	25

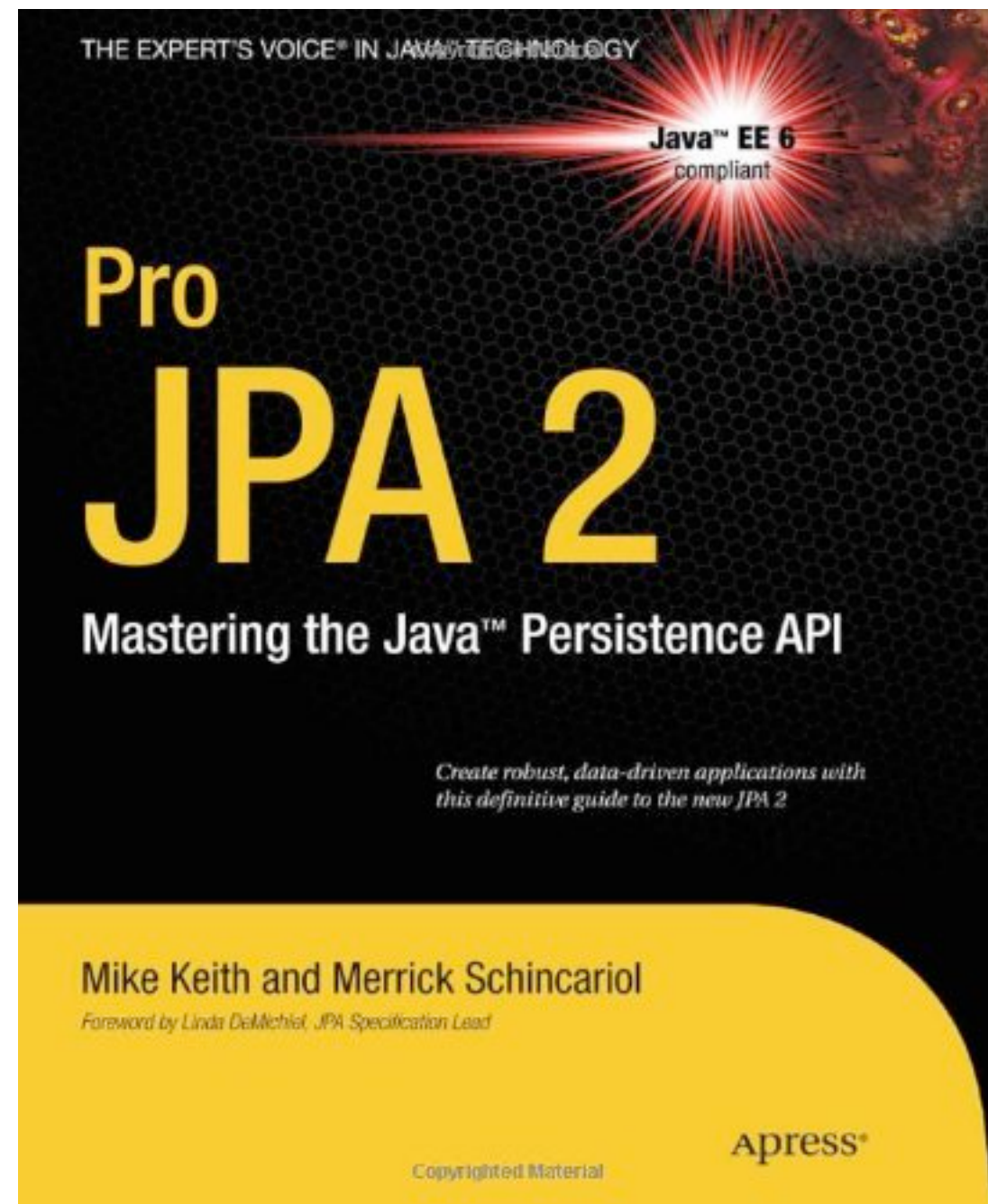
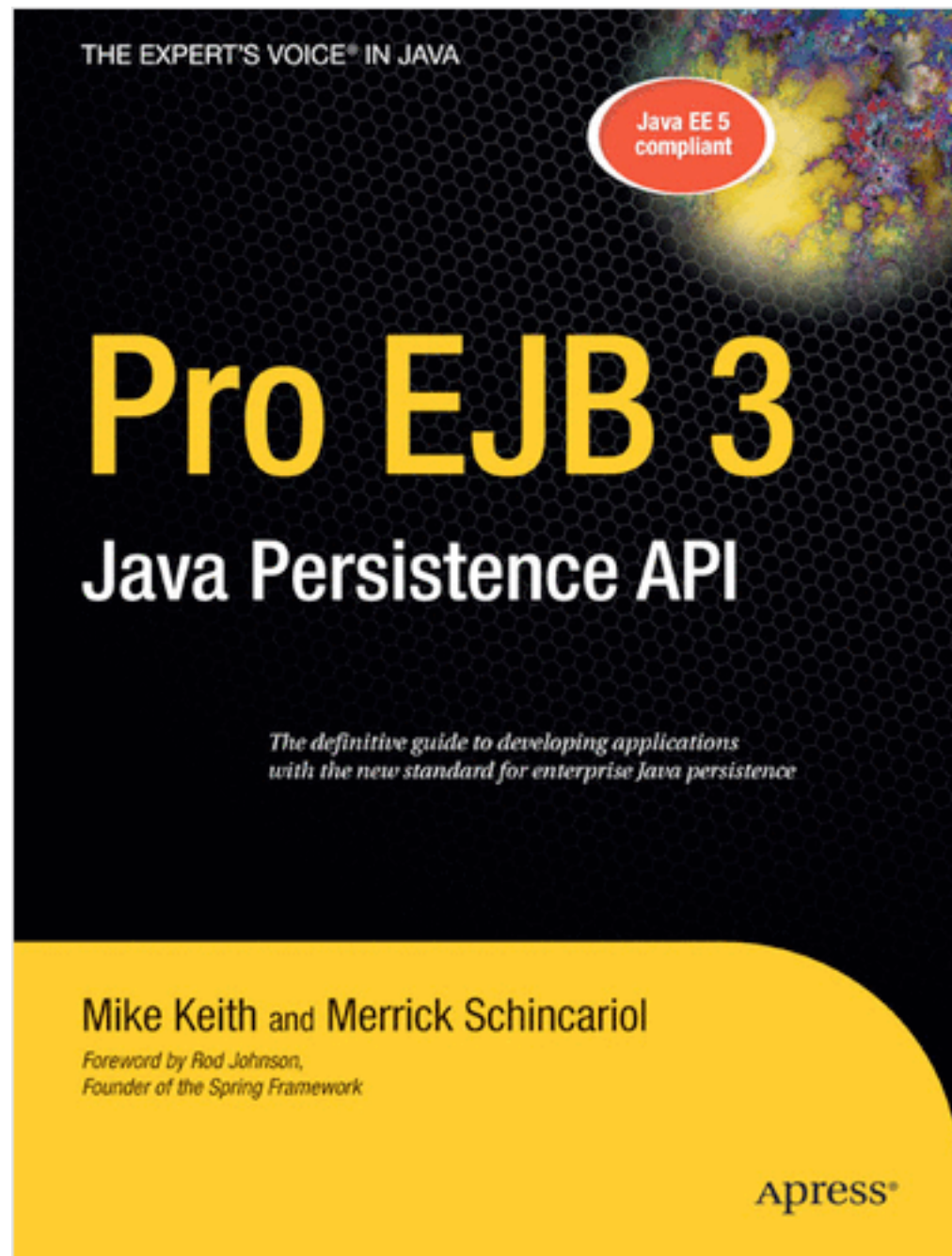
```
Customer customer = CustomersManager.findById(101);  
customer.getOrders().get(0).getLines().get(0).getItemRef();
```

```
SELECT ORDERLINE.ITEMREFERENCE  
FROM CUSTOMER  
INNER JOIN TABLE_ORDER on (TABLE_ORDER.CUSTOMER_ID = CUSTOMER.ID)  
INNER JOIN ORDERLINE on (TABLE_ORDER.ID = ORDERLINE.ORDER_ID)  
WHERE (CUSTOMER.ID = 101)  
LIMIT 1
```

The JPA Bible

heig-vd

Haute Ecole d'Ingénierie et de Gestion
du Canton de Vaud





How do I use **JPA** in my application?

- **Step 1 (static): you design your object-oriented domain model**
 - With JPA, every business object is defined as an “entity”
 - Some coding conventions are defined for JPA entities
 - The persistence properties and behavior are specified **declaratively** with special annotations (XML is also possible)
- **Step 2 (dynamic): you interact with a “persistence service”**
 - The environment provides a “persistence service”, that one can use to find, insert, update and delete business objects
 - JPA defines interfaces and classes for this “persistence service”
 - Note: JPA can be used in the EJB container, in the Web container, but also in Java SE applications!



How do I use **JPA** in my application?

```
@Entity
public class Vehicle implements Serializable {
    @Id
    private long id;
    // properties, getters and setters
}
```

```
@Entity
public class Driver implements Serializable {
    @Id
    private long id;
    // properties, getters and setters
}
```

```
@Entity
public class Trip implements Serializable {
    @Id
    private long id;
    // properties, getters and setters
    @ManyToOne
    Driver driver;
    @ManyToOne
    Vehicle vehicle;
}
```

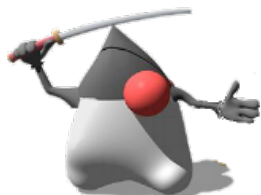
```
@Stateless
public class TripsManager {
    @PersistenceContext
    EntityManager em;

    public long createTrip(Trip trip) {
        em.persist(trip);
        em.flush();
        return trip.getId();
    }
}
```

INSERT INTO Trip (...) VALUES(...);

*With JPA, like with other Java EE API, you can rely on **conventions**. You don't have to explicitly specify all aspects. If you don't, the **standard behavior** applies.*

*But you **stay in control**: if there is something that you don't like about the default behavior, you can change it with different annotations.*

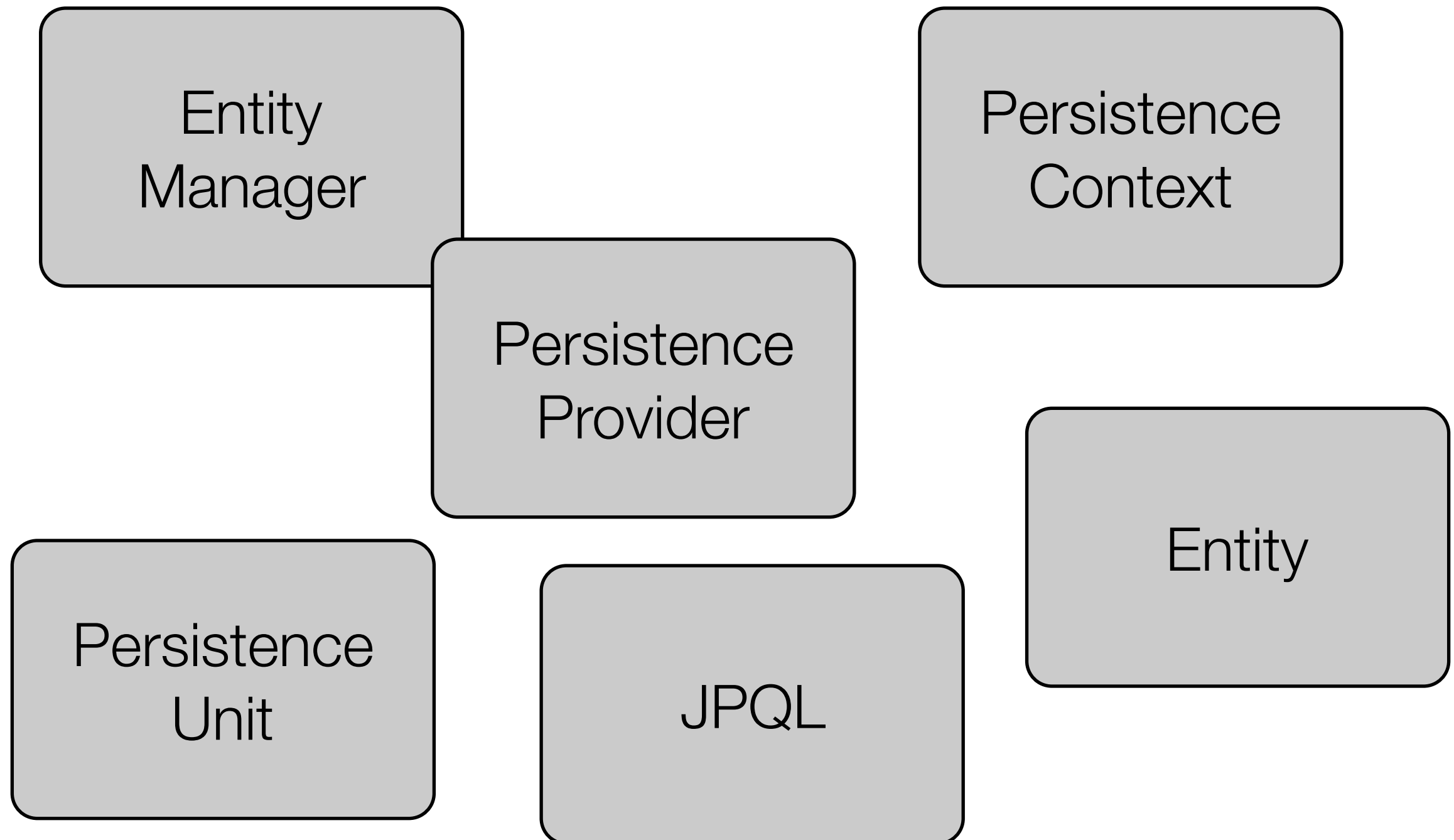


One frequent customization need arises when you have a business **entity name that collides with a SQL reserved word**. For instance, if you have a Role entity, MySQL will not allow you to create a table named Role. In that case, you will need to use the @Table(name="XXX") annotation.

*If you start a project from scratch and do not have to use an existing database, you can **generate the schema** from the Java model. In general, specifying the OR mapping will be pretty easy...*

*If you have an **existing database schema**, then you will need fine control over the OR mapping. JPA gives you this control.*

Abstractions defined in the JPA API



- A Persistence Provider is an **implementation** of the JPA API.
- **EclipseLink** and **Hibernate** are two examples of JPA Persistence Providers. EclipseLink is the one shipped with Glassfish.
- Persistence Providers are “**pluggable**”. This means that if you use only standard JPA features, you can for example decide to switch from EclipseLink to Hibernate at some point (Remember **SPI**?)
- Many JPA Persistence Providers have been created on the basis of **existing ORM solutions** (Hibernate existed before JPA, TopLink as well).
- Many Persistence Providers give you access to non-standard features. You have to **balance** functionality with portability...

- **Remember:** it is not the same thing as a J2EE 1.x/2.x Entity Bean (EJB).
- It is a Plain Old Java Object (**POJO**).
- It does not need to extend any particular class, nor to implement any particular interface.
- This is important, because inheritance can be used to capture business domain relationships (vs. for technical reasons).
- It has a “**persistent state**”, i.e. a set of attributes that should be saved in the persistent store.
- An entity can have **relationships** with other entities. **Cardinality** and **navigability** can be specified for every relationship.

`@Entity` ← This is an entity class

```
public class Student implements Serializable {  
    private static final long serialVersionUID = 1L;
```

`@Id` ← An entity needs a unique id

`@GeneratedValue(strategy = GenerationType.AUTO)` ← There are different ways to generate these id values

```
    private Long id;  
  
    private String firstName;  
    private String lastName;
```

The attributes will be automatically part of the “persistent state” for this entity.

```
    public Long getId() {  
        return id;  
    }
```

If you do not want to persist a field, use the @Transient annotation

```
    public void setId(Long id) {  
        this.id = id;  
    }
```

```
    public String getFirstName() {  
        return firstName;  
    }
```

```
    public void setFirstName(String firstName) {  
        this.firstName = firstName;  
    }
```

```
    public String getLastName() {  
        return lastName;  
    }
```

```
    public void setLastName(String lastName) {  
        this.lastName = lastName;  
    }
```

```
    ...  
}
```

Requirement for a JPA Entity

- The class must be annotated with the `javax.persistence.Entity` annotation.
- The class must have a **public or protected, no-argument constructor**. The class may have other constructors.
- The class must not be declared final. No methods or persistent instance variables must be declared final.
- If an entity instance be passed by value as a detached object, such as through a session bean's remote business interface, the class must implement the **Serializable** interface.
- Entities may **extend** both entity and non-entity classes, and non-entity classes may extend entity classes.
- Persistent instance variables must be declared private, protected, or package-private, and can only be accessed directly by the entity class's methods. **Clients must access the entity's state through accessor or business methods.**

Entity Manager

- The Entity Manager is the **interface** to the “**persistence service**”.
- In other words, it is through the Entity Manager that you:
 - **retrieve** and **load** information from the database
 - **create** new information in the database
 - **delete** data information the database

```
javax.persistence.EntityManager
```

```
<T> T find(Class<T> entityClass, Object primaryKey);
```

```
void persist(Object entity)
```

```
void remove(Object entity)
```

```
Query createNamedQuery(String name)
```

```
Query createNativeQuery(String sqlString)
```

```
...
```

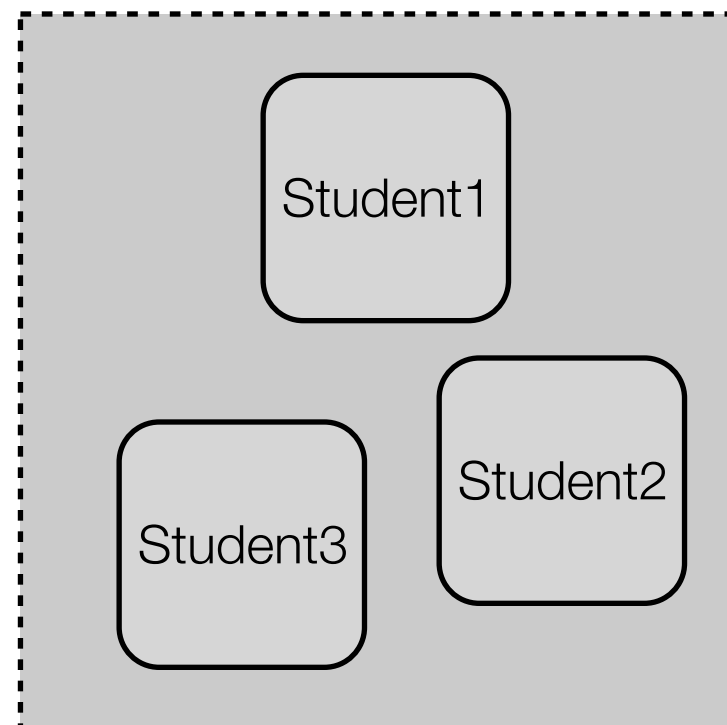
Using the Entity Manager

- You can use the Entity Manager in **different types of components**: EJBs, servlets, java applications, etc.
- Using the Entity Manager from **EJBs** is easy. You simply ask the container to inject a reference to the Entity Manager in a variable, with an annotation.
- Using the Entity Manager in the **web tier** requires some care to deal with concurrency (EntityManager is not thread-safe, EntityManagerFactory is thread-safe).

```
@Stateless
public class StudentsManagerBean implements StudentsManagerLocal {
    @PersistenceContext
    EntityManager em;
    public long createStudent(String firstName, String lastName) {
        Student student = new Student();
        student.setFirstName(firstName); student.setLastName(lastName);
        em.persist(student); em.flush();
        return student.getId();
    }
}
```

Persistence Context

- A Persistence Context is a set of entity instances at **runtime**.
- Think of a **temporary “bag” of objects** that come from the database, that are managed by JPA and that will go back to the database at some point.
 - If you modify the state of one of these objects, you don't have to save it explicitly. It will be persisted back automatically at commit time.
- Using the JPA API, you can manage the persistence context, populate it, etc.



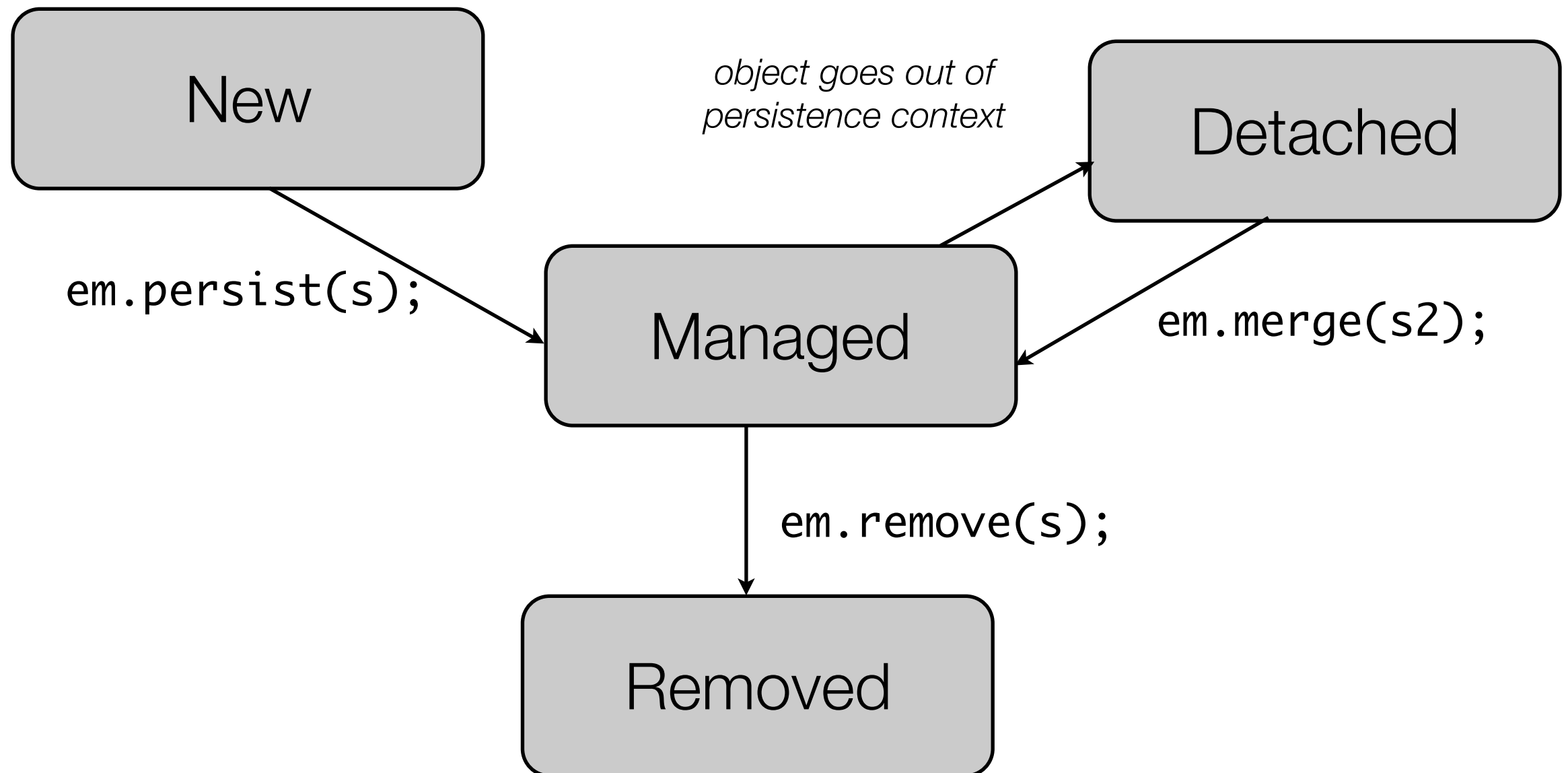
Persistence Context

- “A persistence context is a **set of managed entity instances** in which for any persistent entity identity there is a **unique entity instance**.
- Within the persistence context, the entity instances and their **lifecycle** are managed by the **entity manager**.”
 - “A **new entity instance** has no persistent identity, and is not yet associated with a persistence context.
 - A **managed entity instance** is an instance with a persistent identity that is currently associated with a persistence context.
 - A **detached entity instance** is an instance with a persistent identity that is not (or no longer) associated with a persistence context.
 - A **removed entity instance** is an instance with a persistent identity, associated with a persistence context, that is scheduled for removal from the database.”

Life-cycle for JPA Entities

```
Student s = new Student();
```

*Think what happens when
an EJB returns an object
to a servlet!*





When do objects enter and leave the persistence context?



The persistence context is **created** when **transaction** begins and is **flushed** when transaction commits (or rollbacks).



A **transaction** is started by the **EJB container** whenever a business method is called. It is committed by the container when it returns (or rolled back if there is an exception).

```
@Stateless
public class Manager {

    @PersistenceContext
    EntityManager em;

    public void businessMethod() {
        Customer c1 = new Customer();

        Customer c2 = new Customer();
        em.persist(c2);

        Customer c3 = em.find(123);

        Customer c4 = new Customer(246, "john", "doe");
        Customer c5 = em.merge(c4);
    }
}
```

breakpoint

JVM memory space

JPA Persistence context (managed entities)

c2

c3

c5

c1

c4





```
Customer c1 = new Customer();
```



Creating a new instance of a JPA entity does not make it a managed object. At this stage, it is **a simple POJO** that is not linked to the DB (*)

```
Customer c2 = new Customer();  
// c2 is not in persistence ctx
```



Calling **em.persist(c2)** brings c2 into the **persistence context**. From this point, JPA intercepts all calls made to c2. So, it knows when c2 is modified by a client (i.e. when it becomes **“dirty”**).

```
em.persist(c2);  
// c2 is in the persistence ctx
```



Note that at this stage, it is most likely that **nothing has been written to the DB**. SQL statements will only be issued when the transaction commits.

```
Customer c3 = em.find(123);
```



Calling **em.find(123)** issues a SELECT query to the DB. An entity is created with the result and is **brought into the persistence context**.

```
Customer c4 = new  
    Customer(246, “john”, “doe”);  
Customer c5 = em.merge(c4);
```



c4 is a simple POJO. When **em.merge(c4)** is invoked, a SELECT statement will be issued to retrieve a row where the primary key is equal to 246. A new entity is created and its properties are copied from c4 (to update the DB later on). **WARNING: c5 is in the persistence context, c4 is not!!**



(*) Sort of... see a description of how the magic can happen: <http://struberg.wordpress.com/2012/01/08/jpa-enhancement-done-right/>

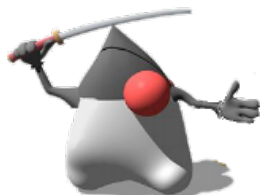
Persistence Context Types

- In Java EE, we typically use a **transaction-scoped persistence context**:
 - The client invokes a method on a **Stateless Session Bean**
 - The container intercepts a call and **starts a transaction**
 - The Stateless Session Bean uses JPA, a persistence context is created
 - Entities are loaded into the **persistence context**, modified, added, etc.
 - The method returns, the container **commits** the transaction
 - At this stage, entities in the persistence context are **sent back** to the DB.
- JPA also defines **extended persistence context**:
 - Entities remain managed as long as the Entity Manager lives
 - The JBoss SEAM framework uses extended persistence contexts: a persistence context lives during a whole “conversation”.

Entity Relationships

- Cardinalities
 - one-to-one
 - one-to-many
 - many-to-many
 - many-to-one
- Bi-directional relationships
 - **Warning:** the developer is responsible for maintaining both “sides” of the relationship!
- Key questions
 - loading behavior: eager vs. lazy
 - cascading behavior: cascading or not? for what operations?

```
employee.setOffice(office);  
office.setEmployee(employee);
```



The developer has the responsibility to “wire” both sides of bi-directional relationships. You will forget to do that. You will not get an immediate error. You will see weird behavior and spend at least 2 hours debugging this.

Entity Relationships

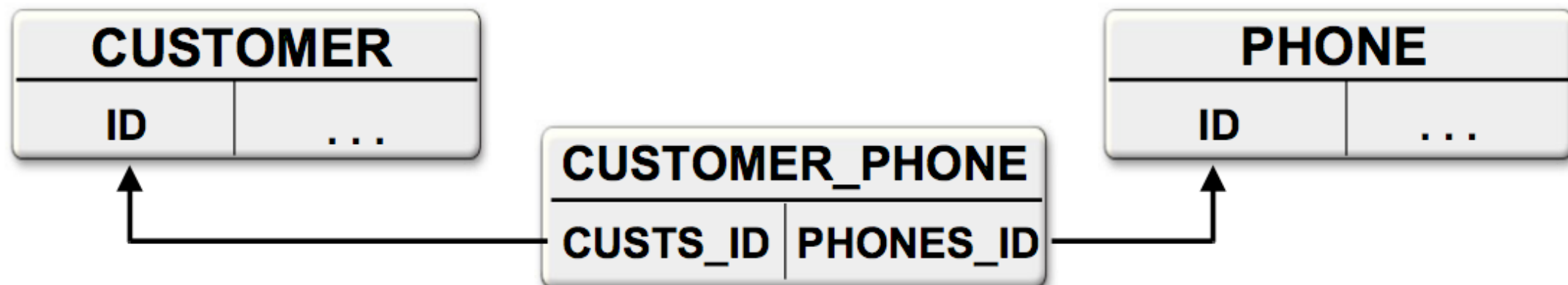
```
@Entity public class Customer {  
    @Id protected Long id;  
    ...  
    @OneToMany protected Set<Order> orders = new HashSet();  
    @ManyToOne protected SalesRep rep;  
    ...  
    public Set<Order> getOrders() {return orders;}  
    public SalesRep getSalesRep() {return rep;}  
    public void setSalesRep(SalesRep rep) {this.rep = rep;}  
}
```

```
@Entity public class SalesRep {  
    @Id protected Long id;  
    ...  
    @OneToMany(mappedBy="rep")  
    protected Set<Customer> customers = new HashSet();  
    ...  
    public Set<Customer> getCustomers() {return customers;}  
    public void addCustomer(Customer customer) {  
        getCustomers().add(customer);  
        customer.setSalesRep(this);  
    }  
}
```


Entity Relationships

```
@Entity
public class Customer {
    @Id
    int id;
    ...
    @ManyToMany
    Collection<Phone> phones;
}
```

```
@Entity
public class Phone {
    @Id
    int id;
    ...
    @ManyToMany(mappedBy="phones")
    Collection<Customer> custs;
}
```



Persistence Unit

- The Persistence Unit defines a list of entity classes that “belong together”.
- All entities in one Persistence Unit are stored in the same database.
- Persistence Units are declared in `persistence.xml` file, in the META-INF directory of your `.jar` file (it is possible to define several Persistence Units in the same xml file).

```
<?xml version="1.0" encoding="UTF-8"?>
<persistence ...>
  <persistence-unit name="SimplePersistenceExample-ejbPU" transaction-type="JTA">
    <provider>oracle.toplink.essentials.PersistenceProvider</provider>
    <jta-data-source>jdbc/demo</jta-data-source>
    <class>ch.heigvd.osf.demo.model.Student</class>
    <exclude-unlisted-classes>true</exclude-unlisted-classes>
    <properties>
      <property name="toplink.ddl-generation" value="drop-and-create-tables"/>
    </properties>
  </persistence-unit>
</persistence>
```


Java Persistence Query Language (JPQL)

- SQL-like query language
- Includes constructs for exploiting the OR mapping. For instance, you can define polymorphic queries if you have defined inheritance relationships.

```
SELECT p
FROM Player p
WHERE p.position = :position AND p.name = :name
```

```
public List findWithName(String name) {
    return em.createQuery(
        "SELECT c FROM Customer c WHERE c.name LIKE :custName")
        .setParameter("custName", name)
        .setMaxResults(10)
        .getResultList();
}
```

Java Persistence Query Language (JPQL)

- You can group all your queries at the same place (vs. directly in the service method). Common practice is to use the `@NamedQuery` in the Entity Class source.

```
@NamedQuery(  
    name="findAllCustomersWithName",  
    query="SELECT c FROM Customer c WHERE c.name  
    LIKE :custName"  
)
```

```
@PersistenceContext  
public EntityManager em;  
...  
customers = em.createNamedQuery("findAllCustomersWithName")  
    .setParameter("custName", "Smith")  
    .getResultList();
```

Summary

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Entity
Manager

I am an interface that components use to interact with the persistence service (CRUD, queries)

Persistence
Context

I am a set of entity instances, at runtime. Often, I live as long as a transaction.

Persistence
Provider

I do the work. I am the implementation of the JPA API. I am Toplink, Hibernate, etc.

Entity

I am a business object, my state will be transparently stored in a database. I am a POJO.

Persistence
Unit

I am a set of entity classes that are mapped to a single database. An EntityManager instance is bound to one persistence unit. I am defined in a persistence.xml file.

JPQL

I am a query language and I look like SQL, but I provide some constructs that take advantage of the OR mapping (e.g. polymorphic queries)